BLOCK OSCILLATION MODEL FOR IMPACT CRATER COLLAPSE. B. A. Ivanov and V. N. Kostuchenko, Institute for Dynamics of Geospheres, Russian Academy of Sciences, Leninsky Prospect 38-6, Moscow, Russia 117939 (baivanov@glasnet.ru).

Introduction. Previous investigations of the impact crater formation mechanics have shown that the late stage - a transient cavity collapse in a gravity field - may be modeled with a traditional rock mechanics if one ascribes very specific mechanical properties of rock in the vicinity of a crater: an effective strength of rock needs is around 30 bar [1], an effective angle of internal friction is below 5 degrees [2]. The rock media with such properties may be named as "temporary fluidized". The nature of this "fluidization" is now poorly understood (see the review of hypotheses by Melosh [3]). Melosh [4, 5] suggests an acoustic (vibration) nature of this fluidization. This model now seems to be the best approach to the problem. The open question is how to implement the Melosh's model (or other possible models) in a hydrocode for numerical simulation of a dynamic crater collapse.

We study more relevant models of mechanical behavior of rocks during cratering. The specific of rock deformation is that the rock media deforms not as a plastic metal-like continuum, but as a system of discrete rock blocks. The deep drilling of impact craters revealed the system of rock blocks of 50 m to 200 m in size [6]. We used the model of these block oscillations to formulate the appropriate rheological law for the sub-crater flow during the modification stage.

1D-model of block oscillation. We formulated the “acoustic fluidization” equations for a simplified model of a single block sliding along the surface. (Fig.1a). Imagine that the block is under the normal load *P* that creates the dry friction force *F*. This force prevents the block motion under the traction *Tr*. Let the block oscillates in a vertical direction with a period *T*. The oscillation creates a sinusoidal variation of the normal load with an amplitude *Sv*. Under this assumption the block is unmoved (velocity v=0) while the vertical load creates the friction force larger than traction. But for the time period t_{free} (see Fig. 1b) friction is less than traction and the block begins to move ($v > 0$). While the normal load growth back to the friction limit, block stops. During the next period of oscillation the block will move again. This simple scheme allows to create the nonlinear rheological law similar to the acoustic fluidisation equations proposed by Melosh [1].

Numerical calculations of crater collapse. The block oscillation model was implemented into the MAC-type numerical code [7]. The simplified model of a crater collapse we used assumes the hemispheric crater transient cavity with initially flat layers deformed in accordance with the Z-model of cratering.

The initial block oscillation velocity was assumed as a fraction of the particle velocity behind the shock front (calculated with another type of a hydrocode). The oscillation velocity decay in space as an inverse square of a distance from the point of impact. The time decay of oscillations was described with an exponential law.

Scaling laws. For the proposed model a set of scaling laws may be formulated. We assumed that for craters of different diameters the block size is proportional to the transient crater diameter. We also assumed the same quality factor for oscillations, which allows to scale results of calculations.

Parameter fit. A set of calculations was conducted to find the model parameters for the best fit to the case of the Puchezh-Katunky impact crater (D~40 km) [6]. The best fit variant is shown on Fig. 3. The frequency of block oscillation needs to be in the range of several Hz, and quality factor *Q* of the order of 10 to 100 to fit the obsurved crater profile. Using the aforementioned scaling law we calculated the collapse of larger and smaller craters to study the morphology of a final crater. Selected results are shown on Fig. 1 and 3.

In the case of a small crater we observed fast decay of vibrations and a simple inward sliding of crater walls. Above some crater diameter the vibration allows the uplift of the crater bottom before the wall sliding, resulted in the central mound formation.

Depth-diameter relationship. The model reproduced the well-known law for complex craters [8]: the maximal depth, d, grows with the crater rim diameter, D, as $d \sim D^{1/3}$.

Conclusions. The large block reformulation of the original Melosh’s acoustic fluidization model with a proper parametrization allow to reproduce the main features of the impact crater collapse: (i) the existence of a critical diameter below wich no collapse occur, and (ii) gradual change of a crater morphology with the crater diameter increase. The block size is a testable parameter at least for terrestrial impact craters. The future work should incorporate the acoustic fluidization from the very beginning of the transient crater growth which may change the simple assumption of the spherical transient cavity used here.

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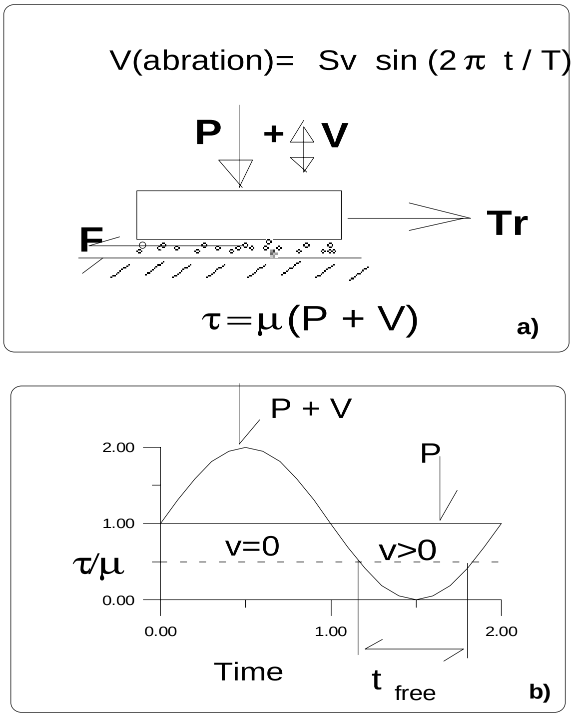

Fig. 1. a) - The scheme of the 1-D model for a block sliding along the underlying surface.

b) - The time variation of the normal load *P+V*. Due to oscillations the friction force is below the strength limit during the period t_{free} , when the block can move under the traction force. See more detailed description in the text.

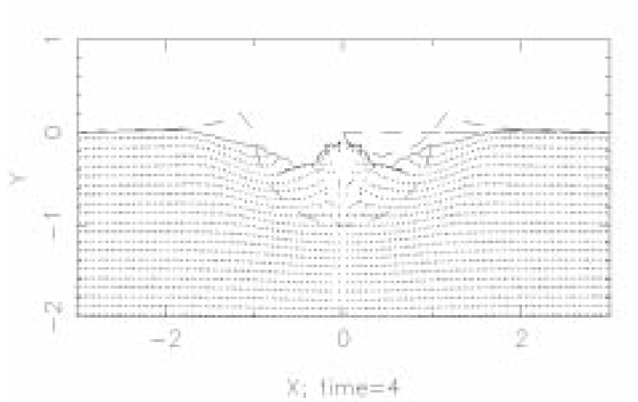

Fig. 2. The final shape of the collapsed crater with a diameter of ~20 km in the terrestrial gravity field. Dashed lines show the initial contour of the transient cavity and (on the right half) the ejected volume. Initially flat marked layers were distorted according to Z-model during the transient cavity formation and then followed to the collapse motion around the crater. The length unite is equal to the transient cavity radius. The time unit is equal to the free fall time from the height equal to the transient cavity radius $(R/g)^{0.5}$.

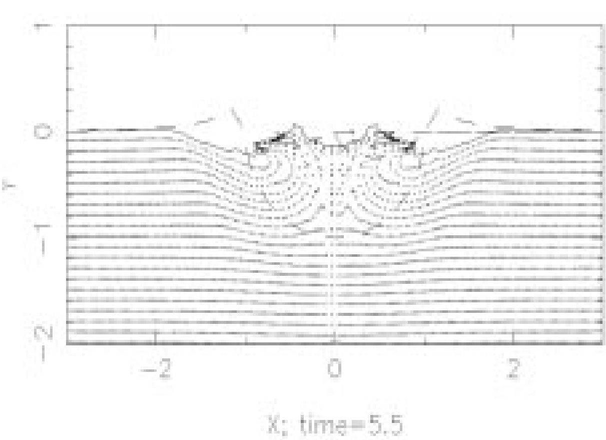

Fig. 3. The same as on Fig.2 but for the crater with D=40 km (Puchezh-Katunki). This case was used to fit the model parameters with the observed morphology

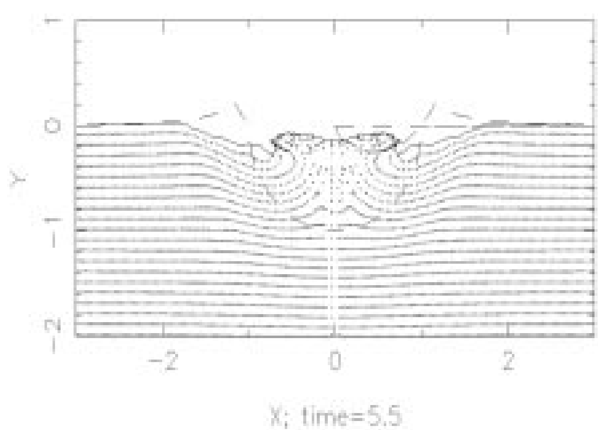

Fig. 4. The same as on Fig. 2 but for the crater with D=80 km. Note the origination of a central peak-ring at the central mound.